

A Revolving Model of Pre-service Teacher Development in Mathematics

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This paper presents a theoretical model for the development of knowledge for teaching, based on a study of primary pre-service teachers (PSTs) in their final year of an Initial Teacher Education Programme. This model arose from findings about PSTs' perceptions of knowledge for mathematics teaching that were related to knowledge of the curriculum, mathematical content knowledge and knowledge of school contexts. The theoretical model describes how PSTs developed this knowledge for teaching mathematics. There are three phases in this model; *recognising* crucial aspects of teaching, *reconceptualising* these aspects, and *realizing* these aspects in a mathematics classroom. In conclusion I discuss the possible use of this model for my work as a teacher educator.

Knowledge needed for teaching is an important consideration for teacher educators because they are charged with the responsibility of preparing teachers to teach in the classroom. The seminal work of Shulman (1986) highlights the complexity of this knowledge and lists different categories of knowledge for teaching. Grossman (1990) represents these categories of knowledge for teaching to include, "general pedagogical knowledge, subject matter knowledge, pedagogical content knowledge and knowledge of context" (p. 6). These four categories are significant as they influence and inform the content of Initial Teacher Education (ITE) programmes, whose goal is to prepare PSTs for teaching. In the field of mathematics education several authors agree that the task of learning to teach mathematics is complex (Ball, 1993; Hill, Sleep, Lewis & Ball, 2007). PSTs need to not only *know* what to teach that is subject or mathematical content knowledge; they also need to know how to teach this content. Sowder (2007) describes the knowledge needed for teaching mathematics as "a blend of subject knowledge and an understanding of how to deliver this" (p.173). Mathematics educators within the ITE setting then need to decide how to support PST to develop this knowledge. Ball (2000) describes this as needing to identify content knowledge that matters for teaching, understanding how such knowledge needs to be held, and understanding what it takes to learn to use such knowledge in practice.

Within the ITE setting PSTs develop knowledge for mathematics teaching from different sources such as course work and Professional Practice experiences. In addition they bring with them their own knowledge of mathematics for teaching which Shulman (2004) describes as their "intellectual biography." PSTs need to construct knowledge for teaching mathematics from all of these sources and transform this knowledge for use in a mathematics classroom (Fennema & Franke, 1992; Winsløw et al., 2009). This paper presents a model for the development of knowledge for teaching mathematics in an ITE setting. This model evolved from a research project that aimed to identify the needs and concerns of third and final year PSTs as they prepared to teach mathematics in a primary school (Wilson, 2010). In this paper I firstly describe this model which is entitled, "The Revolving Model of Pre-service Teacher Development"; secondly I present some data relating to the model and finally I discuss the use of the model for my work as a mathematics teacher educator.

The Emergence of the Model.

One of the mathematics courses I teach within the Bachelor of Teaching and Learning degree is a third and final year course which is held over five weeks. This optional course was the context for the research project. Each year I endeavour to include course curriculum that meets the needs of the students, within a tight timeframe. Ensor (2001), citing the work of Bernstein (1996), refers to course curriculum as “privileged repertoire” which is defined as, “the set of symbolic and material resources that teacher educators (and teachers) select and configure in order to shape their classroom practice” (p. 299). As I prepare this curriculum I am faced with the dilemma of *what* to select and *how* best to present this. My challenge is to select and teach a “privileged repertoire” to prepare the PSTs for the realities of teaching mathematics in their own classrooms. I also need to take into account the knowledge about mathematics teaching they bring with them from their previous two and a half years of teacher education. Twelve course members volunteered to participate in the study and data was collected over the five weeks, using two questionnaires and two interviews of focus groups. The data were analysed for themes and resulted in two significant findings. The first finding related to *what* knowledge the PSTs needed for mathematics teaching; curriculum knowledge, content knowledge and knowledge of school contexts, as explained by the work of Shulman (1986) and Grossman (2000). The second finding revealed a process related to *how* they constructed this knowledge for mathematics teaching. I identified three active phases of knowledge construction which are; *recognising* aspects of knowledge for mathematics teaching, *reconceptualising* this knowledge for teaching, then *realising* it for enactment in a mathematics classroom. This evolved into a model for teaching, entitled “The Revolving Model of Pre-service Teacher Development”. Each of these phases is described below:

Recognising: this refers to the aspects of knowledge for mathematics teaching the PSTs *recognised* when they engaged with the different sources of knowledge in their ITE course. “Recognising” means to notice, and to identify elements of effective mathematics teaching (Walshaw & Anthony, 2007). This phase is closely aligned with the work of Mason (2002) and Sherin and van Es (2002) who write about the importance of noticing as a process for effective mathematics teaching. Sherin and van Es (2002) describe a key aspect of noticing as being able to identify what is important or noteworthy when teaching mathematics.

Reconceptualising: refers to how PSTs formed and reformed their ideas about mathematics teaching, after the process of recognising. This includes thoughts, feelings and actions they engaged with to develop their own understanding of effective mathematics practices. This reconceptualising phase is also informed by two other important aspects of noticing described by Sherin and van Es (2002), as being to make connections between classroom interactions and broader principles of teaching, and to learn and use what one knows about the context to reason about classroom events. This phase acknowledges a constructivist view of learning where new learning is connected to existing knowledge (Borko & Putnam, 2000).

Realising: refers to the processes they engaged with to realise, or “make real,” their new knowledge about mathematics teaching for use in the classroom. This includes both intended implementation of knowledge in practice such as what they might plan to do in their classrooms, as well as the actual implementation in a mathematics classroom. For PSTs this can occur within course work by engaging with tasks which mimic “real” tasks teachers would do, for example when planning for mathematics teaching, and when teaching mathematics during Professional Practices. This phase aligns with the work of

Ensor (2001) who emphasises the importance of enacting plans as a crucial part an important part of learning to teach.

Each of the three phases can be considered as a discrete process, however when put together presents a connected and revolving process for knowledge construction. To best represent this connected process I developed a visual model which is illustrated in Figure 1 below:

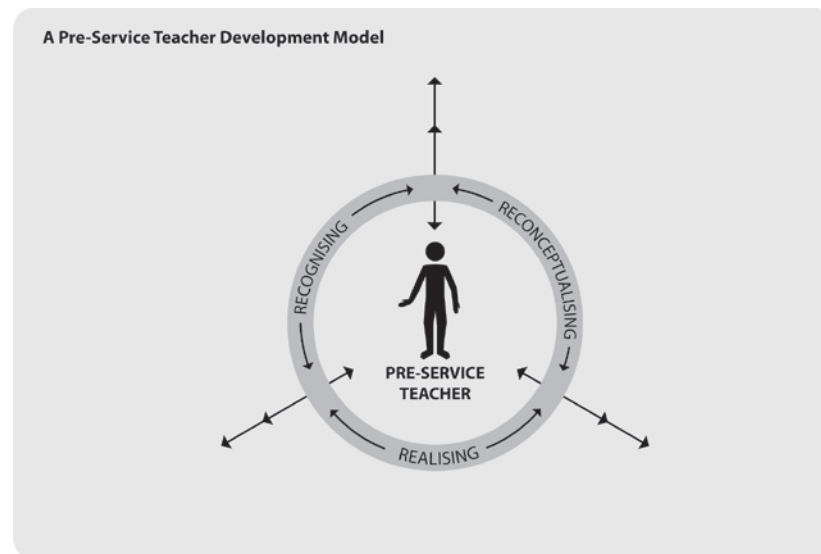


Figure 1. A revolving model of pre-service teacher development.

The PST is placed at the centre of the model because their data informed the construction of the model. The three phases of recognising, reconceptualising and realising are presented in a circular form to illustrate the cyclic revolving motion, both forward and backwards, of knowledge construction for each individual PST. “Revolving” relates to ideas about moving and turning, as well as thinking, considering and focusing, all of which are applicable to a dynamic learning process. The model engages the three domains of curriculum knowledge, mathematical content knowledge and knowledge of school contexts and occurs over different time spans and different contexts for each PST. When combined, the model presents both *what* the PSTs wanted to know and *how* they came to know it within their ITE course. This is presented in Figure 2 below:

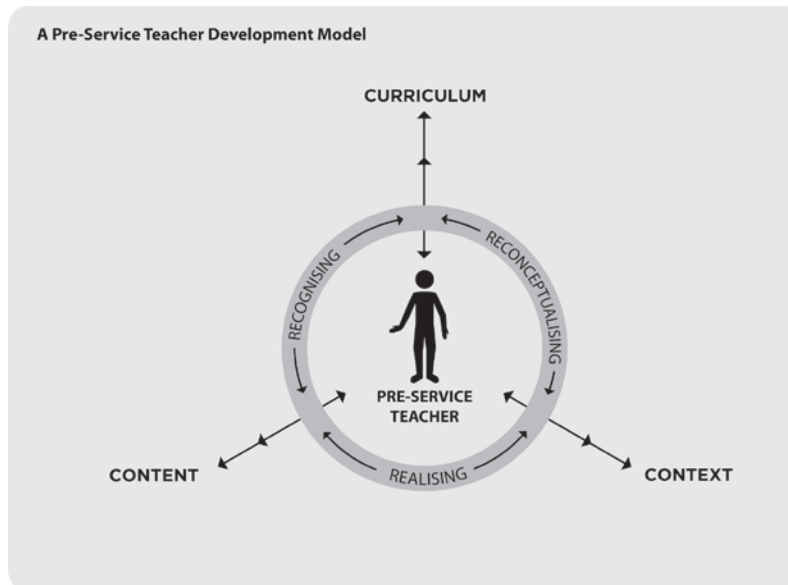


Figure 2. A revolving model of pre-service teacher development.

The following examples of the model in action are drawn from data from a group of PSTs during the development and completion of a course assessment task. This task required the completion of a long-term plan in mathematics, based on the Mathematics and Statistics learning area of *The New Zealand Curriculum*, (2007). For the PSTs in the study, this was the first time they had worked with the new curriculum. They had to engage with the curriculum, select and combine achievement objectives to form units of work and write key mathematics ideas to summarise the mathematics content for each unit.

The Revolving Model in Action

Recognising: PSTs recognised the long term plan as an important document they had seen on Professional Practice that contained curriculum content and provided direction for teacher’s planning. Despite this they were unsure about didn’t the content of the plans, the purpose of the plans or how they had been put together. On receipt of a plan on placement Marie described it as “just words on a page...blah,blah,blah”, and Daniel admitted it was a document he thought he had to collect to meet a requirement, “when I get a long term plan on Professional Practice I don’t pay much attention to it- it’s there to fill up my folder”. When working with the Mathematics and Statistics learning area of the curriculum to complete their own plans they started to notice different aspects. They recognised the strand headings i.e. number and algebra, geometry and measurement and statistics as being a reconfiguration of the old curriculum document headings. They noticed the inclusion of content from The Number Framework (Ministry of Education, 2000). While they were familiar with this content they had questions about how The Number Framework aligned with the new achievement objectives. An important part of noticing is recognising what they don’t know, which occurred for several PST when they engaged with the curriculum achievement objectives. Within the objectives they identified problematic and unknown mathematical topics and vocabulary, for example, fractions, decimals, algebra, knowledge and strategy. Tui described some of the vocabulary in the objectives as “lingo”, stating “it’s just a bunch of words”. She explained, “Algebra is just a word. I don’t really know, I couldn’t tell you what it is”. In relation to The Number Framework content she said, “I didn’t know the difference between knowledge and strategy...I’ve heard the terms before,

but didn't know what they meant". The PSTs recognised they needed an understanding of the mathematical content included in the objectives and actively sought resources to develop this knowledge.

Reconceptualising: PSTs scrutinised and analysed the curriculum achievement objectives looking for clues for information about the mathematics they had to teach and how they could teach it. The glossary from the old curriculum and a variety of dictionaries were used to define unknown terms for example, decimals, fractions, and algebra. Some relied on the verbs in the objectives to explain how to teach the content; "like when I looked at the achievement objectives I found them really useful for examples, if you're saying describing and investigating then that's what you have to do. Yip I found that really useful" (Daniel). Cross checking the old achievement objectives with the new, helped to construct content understanding. Teaching resources were used extensively to clarify the meaning of mathematical terms and for guidance about how to teach the concepts. Ministry of Education resources were also used extensively, particularly web based resources. Teaching resources that originate from the Ministry of Education are trusted as reliable sources and resources of knowledge to supplement curriculum and content understanding (Wilson & McChesney, 2010). The PSTs engaged in a sense making process by continually reasoning about curriculum and mathematical content, and moving between the curriculum and other resources. By deconstructing then reconstructing curriculum content they were able to develop both curriculum and mathematical content knowledge.

Realising: within the context of writing the long term plans, the PSTs were able to realise curriculum and mathematical content knowledge. While their mathematics plans were not able to be implemented in a classroom the task allowed them to engage in a realising process in the context of this course. They rated the task as a highlight of the course, because it simulated both a product and process they would engage with as "real" teachers. Armed with this knowledge they were excited by the prospect of being able to, as beginning teachers, work alongside teachers and contribute to collegial curriculum planning. Kate explains this, "You can now participate in unit planning and long term planning because you have done it. You can feel a part of this going into a school, rather than sitting there and going, I have no idea how to this". The planning task not only helped them to transform curriculum and content knowledge for teaching, it also helped their transition into the role of a beginning teacher. The intended realisation of the plan completed in the course setting, helped prepare them for the actual realisation of a plan in their own classrooms. This was a realising of both future teaching and a connection with future classroom responsibility.

Use of the Model for ITE.

The experience of each phase of The Revolving model highlights the complexities of the processes that PSTs engage with to develop knowledge for teaching while they move between the different components of their ITE programme. For PSTs there is a danger that different course components can become separate and disconnected. In order for learning to occur across and between course components, PSTs and teachers educators need to "bridge the gap" between these experiences (Ball, 2000). The three phases of the teaching model; recognising, reconceptualising and realising, show how this could occur. The model represents how PSTs recognise familiar and unfamiliar aspects of privileged repertoire for mathematics teaching, make sense of these, and then realise them in practice. In addition the model provides a sense making process when course components present contrasting and/or conflicting messages about effective mathematics teaching (Goos et al., 2009). It places the

PST at the centre of a decision making process and encourages them to construct knowledge for mathematics teaching from a diverse range of course experiences.

In the model the PST is positioned in the centre of the diagram with an open posture and an outstretched hand. I decided to do this deliberately to acknowledge a quote by Shulman (2004) who describes the complexity of pedagogical knowledge for teaching as being “both a handful and mind-full” (p. 513). The “mindfull” represents the vast amount of knowledge available for mathematics teaching, for example, the mathematics, the curriculum, resources, activities, and assessment practices, while the “handful” represents the portions of this knowledge PSTs can select for implementation in a mathematics classroom. Placing them at the centre of the diagram surrounded by a circular process emphasises their ongoing and active process to construct knowledge about the curriculum, mathematical content and school contexts. It also reinforces the PST as the learner, who as a novice teacher is beginning to make their ‘own’ decisions about a privileged repertoire for mathematics teaching. While experienced teachers have their own repertoire to draw from for enactment in the classroom, PSTs need to develop this. “Experienced teachers may possess rich repertoires of metaphors, experiments, activities or explanations that are particularly effective for teaching a particular topics, while beginning teachers are still in the process of developing a repertoire of instructional strategies and representations” (Grossman, 1990, p.9). The revolving motion of the circle also highlights that knowledge construction involves more than imitating the privileged repertoire presented by teachers while on Professional Practice, or in course work, rather PSTs need to generate their “own” repertoire. This occurs over time and at different rates depending on PSTs experiences. The outstretched hand also indicates the collegial nature of the knowledge construction process because the PSTs developed knowledge by working both individually and collectively. Collegial processes within the ITE setting align with collegial processes in school settings and help prepare PSTs for transitioning between the two (Winsløw et al, 2009). Within the course the PSTs participated in a workshop which simulated a teacher meeting to develop their long-term plans. The ‘hand’ in the diagram acknowledges the input of others in the knowledge construction process.

The circular diagram also challenges the notion of “learning to teach” as being a linear process. This study has highlighted the many cycles of learning for the PSTs both within between and course experiences. For each PST these cycles accumulate along a continuum of learning, commencing within an ITE programme and continuing when they move into school settings. The model has potential as a professional learning model in their own classrooms, where they will continue to develop curriculum, mathematical content knowledge and knowledge of their contexts by recognising, reconceptualising and realising aspects of effective mathematics teaching from their individual school settings.

The identification of the revolving model has helped my work as a teacher educator because it presents categories of knowledge for teaching mathematics as well as a process for developing this knowledge. The identification of knowledge about curriculum, mathematical content and contexts helps to inform decisions I make about the privileged repertoire of mathematics teaching included in the course. Rather than making assumptions about this course curriculum I can feel assured that by addressing these three areas I will be meeting the needs of the PSTs. The identification of curriculum content highlights the need to include in-depth work on the Mathematics and Statistics learning area of NZC (2007) and the Number Framework document. The identification of mathematical content highlights the need for the inclusion of this content within an ITE programme and raises questions about how best to teach this within the constraints of short courses and within already crowded

ITE programmes. As a teacher educator, prioritising what content to include always comes at a cost of leaving content out. This continues to be a dilemma for me.

The identification of the long-term plan as a valued task by the PSTs stresses the importance of selecting and providing tasks which simulate the reality of the classroom. This is particularly important for PSTs who experience separate and short Professional Practice experiences and who do not have their own classrooms to situate their learning (Borko & Putnam, 2000). I did not set out to evaluate the long-term plan as an assignment, but PSTs unanimously agreed it was one of the most useful assignments they have done in their ITE programme because it provided a “real” task that real teachers did. It was also valued because the task was a vehicle for developing both mathematics curriculum and content knowledge. This information serves to support the decisions I make about the benefits and appropriateness of mathematics assessment tasks selected for inclusion in the mathematics course, and the role they play in preparing PSTs for transitioning to various classroom settings as Beginning Teachers.

The model is an important contribution to the field of mathematics education, because it articulates a process for learning to teach mathematics both within the ITE setting and beyond. Much is known about *what* PSTs need to know in order to teach mathematics, but not a lot is known about *how* they transform this knowledge for teaching (Fennema & Franke, 1992). Ball (2000) summarises this by stating, “It’s not just what mathematics teachers know, but how they know it and what they mobilize mathematically in the course of teaching” (p. 243). The revolving model sheds lights on this process; *recognising* emphasises the need for PSTs to recognise both familiar and unfamiliar, congruent and incongruent aspects of effective mathematics teaching, *reconceptualising* acknowledges the need for time, spaces and resources to deconstruct and reconstruct meaning from the recognising process, and *realising* highlights the importance of grounding these understandings in the intended or actual reality of the mathematics classroom. In a recent article, Spalding, Klecka, Lin, Wang and Odell (2011) ask how teacher education programmes can support and challenge PSTs to develop “self” as a teacher, this paper presents one model which could help address this.

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